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II.

STARTING from the principle of modern psychology that unity of mental operation is found in response through action, not in the sensation or ideas preceding the action, we can proceed to the corollary that the children's activities represent the concrete side of education and furnish a point of attack. Sensation represents the stimulus to the act, thought the process of making the proper response. From the point of view of this psychological principle the problem of elementary science, then, is: What *activities* furnish opportunities to be used in the growth of scientific method and concepts?

It is a common observation that the child's activities vary in different periods of development,[1] and the following rough classification of his attitude in them might be made: During the first period, from four to six, they are direct and social. He undertakes no long processes with remote ends. The next three years, from six to nine or ten, belong partly in the period of direct activity and partly in a second period, from nine to about twelve or thirteen, where immediate ends are no longer demanded, and where the social interest, although still dominant, begins to yield in force to the dawning intellectual interest. At about twelve or thirteen we come to the age where the beginning of interest in abstraction and formulation marks the beginning of

[1]See *Elementary School Record,* article on the Psychology of Occupations.

the so-called secondary period of education, when the work can approach in method a scientific ideal.

The above classification will determine the choice of subject-matter from the side of the child's motive, while the scientific generalizations of the teacher play but a secondary part; hence any illustration of the way in which these concepts actually work in experience is secondary to, and must be deferred until after, the consideration of the way in which the child grows in particular scientific ideas. For example, the concept of the conservation of mass and of energy is always implicitly present in the teacher's mind and is one factor in the selection of the subject-matter, while it may be years before the child will be able to appreciate the intellectual value of such a concept, even in part. The following is a brief outline of possible selections of subject-matter corresponding with the periods of development:

During the first year of the first school period (from four to six), in the household and neighborhood occupations chosen as the subject-matter, the particular processes—*e. g.*, cooking, sewing and weaving—are carried out largely through imitation. In the modern social occupation chosen for the six-year-old child the typical ones which furnish food, shelter, and clothing are selected, and here an initiation of conditions or of experiment can be made only in those processes which deal with very familiar material, such as cooking, simple constructive work, and the housekeeping of the class-room or kitchen. The next year, in the summary of primitive history, through occupations from the side of invention and discovery, through imitation is introduced what might be legitimately called experimentation, in cooking, in constructive work, and in carrying on the occupation developed.

The next two years, from eight to nine, might be selected as belonging peculiarly to a transitional, intermediate period. The problem of selection here, as in the first stage, is still social rather than scientific. During the first year of this transition period more initiation and experimentation on the part of the child is demanded by the method of treating social material used. The

occupations are of definite peoples, in actual localities, and have assumed more limited and specialized form. The processes used should be distinctly experimental, the imitation indirect, through memory of past experience or through relation of the results of others' experience, thus involving actual manipulation by the child of the conditions involved. In this year also, without distraction or inhibition of activity, he can formulate simple conditions necessary in the initiation of any experiment, and also consciously apply the result of this experiment in any process he is carrying on, such as spinning, cooking, or constructive work of any kind. The method, however, in which any selected process is carried out is more experimental, involving not only more initiation on the part of the child during experimentation, but also carrying over of the results of experimentation and applying them as rules, principles, or laws to new material.[2]

The particular processes selected would depend entirely on the child and the teacher, although with the former's increasing experience and ability there no longer exists the urgent need for the background of a common experience which is one of the strong factors influencing the choice of material in the beginning of school life. Here the personal element may come in through the life of the people concerned in carrying on the occupation or the process studied. This factor limits the choice to some industry or process either actually going on in the child's immediate neighborhood, or carried on by people about whom he is studying in the more distinctively social or historical work of the school.

As a matter of convenience, during the latter year of this transition stage it is possible to take up what might seem to involve a decided differentiation in studies. For instance, in studying the topography of any locality with which he is concerned, instead of gathering up all the facts as springing from the lives of the people of this locality, he is able, without feeling any break in continuity, to work up the resources of the region under classified heads; for example, to take up the problem of

[2] See MISS HARMER's articles on "Cooking" and "Textiles" in the June number of the ELEMENTARY SCHOOL TEACHER.

what routes would be used for transportation to neighboring countries, and to work out these routes from the topography of the map; or, being given the mineral resources of the region, to work out the industries which spring up as a consequence of these resources. In the same way, in his experimental work, he is able to take some process, such as the making of alloy, like pewter, and to carry over inductively any principle he has discovered and apply it in the making of a new alloy involving the use of new metals. The processes used can be longer, more varied, and initiated by the child from the nature of the conditions and material at hand, through the use of experiments to bring out the need for each step. Here also experiments can be used to separate out one factor of a complicated process as an illustration of the principle of that process; for example, experiments can be given illustrating the relation of chlorophyl to the making of starch, as a part of the plant's life-process.

In the first year of the second elementary period, at the age of ten, the children seem ready to work out experimentally complicated processes in detail. This method of working out the operations used in an industry not only gives some idea of the part which experimentation actually plays in manufacturing, but also gives the beginning of the scientifico-sociological attitude through the concrete formulation of the difficulties to be met in any manufacturing process—the idea of the method of procedure in obtaining crude material, including storage and transportation; the processes gone through in the preparation of that material, involving perhaps the combination of resources from different sections of the country; and finally the placing of the product on the market, involving advertisement, and the manufacturer's relations to the middleman, the wholesale merchant, and the retail merchant.

During the second year of this second period, at eleven and twelve, children are not only ready for the continuation of complicated processes worked out in detail, in connection with some occupation or industry, but are able to work out concretely simple laws, such as the law of the lever, and apply them subsequently in the making of simple machines and apparatus. They

begin to comprehend the need for such units as are involved in the measurement of work; that is, of course, such units as do not involve the idea of acceleration.

Both because the problem itself becomes more complicated and because the field of choice of material becomes exceedingly wide, any definiteness of suggestion is impossible either for these last two years of the elementary period or for the beginning of the secondary period. The beginning of this so-called secondary period of education is marked by the beginning of interest in abstraction and formulations, and hence the beginning of work which can approach in method and subject-matter the scientific ideal. Although oportunities for observation and experimentation here have been much more limited, results would seem to guarantee the general conclusion that, while in this period the child possesses a dawning interest in abstraction, yet it is a mistake to approach whatever portion of the scientific field may be selected from the side of formulation. It is still necessary that all possible connection be made through the selection of material and processes constantly present in the child's own life, and to use these as points of contact with the general ideas which he is now able to manipulate.

A general division of observational and experimental work, from an adult point of view, has been made in nature-study. It would seem that no such distinction exists during the first period of direct activity. Observation and experimentation are the two sides of one process mutually interacting. The child shows the beginning of an observation akin to adult observation, in which the reflective and motor impulses are held in abeyance in periods of quiescent attention to new objects and phenomena. This attention, if no interruption occurs, inevitably seems to lead to action or experimentation with the child. The child's interest in experimentation is, of course, only one form of activity, but the distinction here made, for our present purpose, between the experimentation called observation and the distinctly active experimentation is that in the first the child is a more or less quiescent spectator of natural processes, while in the second he more or less controls and initiates conditions. These two atti-

tudes, of course, overlap until, in the latter half of the elementary period, the child reaches the stage of interest in his own formulation of causes, and unconsciously experiments, rushes in to effect changes himself in what is going on, or actively investigates hidden causes.

To illustrate in brief the way in which the general concept in the teacher's mind may serve as a unifying principle in the choice of work, as contributing toward the child's ultimate formulation of a scientific concept, the idea of force and of matter as controlled through measurement might be taken. In the very earliest use of weights and measures the weights must be used by the child as a way of determining quantity through the pull of the earth upon matter, or gravitation. The scales are a device for finding equal pulls. The necessity for the use of this kind of measure which will appeal to the child could be found in many processes, but may be illustrated by the use made of it in cooking. One of the first operations which the child carries on in the cooking of cereals necessitates the use of flaked rice, which combines with an equal bulk of water, as the unit which determines the amount of water to be used with each bulkier or more compact cereal. This kind of comparison of quantity as obtained by measurement and mass as measured by the pull of the earth can enter into almost any process which he carries on during the first two years. By the time he has entered the transition period he is ready to formulate a rational system of weights and measures either in connection with the people who develop such a system or with the modern use of the metric system. The ways by which this constant reference to the force of gravity can be made more and more explicit in the child's mind are numerous and will present themselves to everyone. As referred to above, when his work on the simple machines begins, he is ready to use the notion of measuring work by units of weight carried through units of space, to understand the proof of the earth's motion by the swing of the pendulum, and in many other ways to interpret the action of this ever-acting gravitational force on animals and plants, or as used in the barometer and in water-power.

Among other topics which can be taken up in this spiral fashion would be the part that plants play in rendering the energy from the sun available for animals. In the first period this topic would inevitably be treated, though not consciously formulated, in connection with all the work in which the children are engaged. The third year's work would especially illustrate, in the life they study, the present dependence of man and domestic animals upon the vegetable world. The next or fourth year would add something to the way in which man has developed these resourses of the earth. The fifth year would add very striking and diverse types of such dependence, showing in the Esquimos a type almost independent of vegetable life, and in the tropics life reduced to its lowest terms of absolute dependence upon vegetable food. The sixth year would begin the first conscious work, when the problem of plant food, and, in the cooking, the ways to make it available, are considered. This would involve the classification of the different forms in which this food is stored and made use of by man. In the seventh year there would be taken up definitely the relation of the storing of this food by the plant to the source of energy, the sun's light. Ideally, in the year following, the eighth, the difference in function in plant and animal, in nutrition, would be taken as a conscious problem; and with the work in mechanics some idea would be gained of the fact that the different forms of energy are all measurable, and that the relation of the human body to its food is roughly analogous to the dependence of a machine upon its fuel.

Another type of general ideas which becomes explicit much earlier than those just used is represented by the concept of the earth as a whole. This naturally grows up through the incidental contact of the child with peoples and countries, and also in the repeated use made of the seasons of day and night change. The ever-present interest in the world as related to other worlds than ours shows itself as early as seven, and grows more definite at eleven or twelve, when the child is ready for formulation of ideas of this type.

As we watch the developing child, we find this continual inter-

play of the activity of observation, of experimentation, reflection, and application in a new activity, growing more and more definite and controlled. The first generalizations of the child are concrete in form. He inclines to make no formulation of results in terms of the processes that lead up to them, but to pass over into a new activity which involves the principle or idea obtained in the previous activities or experimentation, and which would have been impossible save for the presence in their minds of the conclusion arrived at from the preliminary experience. As the end of the activity becomes more remote, the consciousness of the steps to that end also grows, until we finally reach the more conscious swinging of the mind from observation and experiment to end in view—to reflection upon results, to recognition of principle and law, and again to renewed observation and experiment, and extension to new phenomena and experiments of the old principle passing into a new, so developing the controlled mind we call scientific.

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